Quarterly Progress Report

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FUNDAMENTAL STUDIES OF THE METALLURGICAL, ELECTRICAL AND OPTICAL PROPERTIES OF GALLIUM PHOSPHIDE

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PROJECT 5115: SEMICONDUCTOR DEVICES FOR HIGH TEMPERATURE USE

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The purpose of this project is to prepare power rectifiers and solar batteries which will operate at temperatures up to $500^{\circ}C$. During this quarter, work has progressed on the method of forming an ohmic contact by alloying in a vacuum. It is believed that the results found are of significant value in the realization of reliable ohmic contacts.

Picovac Sputter-Ion System

As stated in the last quarterly report, modifications had been made to the new Varian sputter-ion (picovac) system through the addition of substrate heating and thermocouple monitoring such that alloying could be accomplished immediately following the evaporation of a metal contact. With these modifications, several attempts were made to alloy nickel-germanium mixtures to n-type, tellurium doped, GaP with a carrier concentration of 2×10^{17} cm^{-3}. However, none of these attempts were successful. The physical configuration of the picovac with the single viewing port at the top of the chamber does not easily permit the close observation of the surface which is necessary to determine the temperature at which the alloying takes place. Furthermore, during these trials the picovac system continually degraded until the time required for an evaporation was no longer acceptable. After consultation with the Varian field engineering representatives, the system was returned to Varian to replace the sputter-ion pump which was thought to be defective, to test all valves, and to clean the vacuum chamber thoroughly. Upon the return of the system, tests were made which unfortunately revealed that the problem had not been solved. The ultimate vacuum attainable remained greater than an order of magnitude poorer than our earlier results and pump down times were similarly increased. The unit was therefore returned again to Varian for repair where it now remains. The latest reports are that a leak has been found in the high vacuum valve and that the design of the top closure may be faulty. Therefore a decision was made to abandon the picovac system for the ohmic contact study, at least for the present.

Alloyed Ohmic Contacts

The ohmic contact effort was then transferred to the evaporation and alloying in a standard oil-diffusion vacuum system and encouraging results were obtained. After several unsuccessful attempts, the following system was adopted:

Approximately 60 milligrams of a nickel germanium mixture were evaporated from heavy multi-stranded tungsten filaments onto the GaP samples which were clipped to a high purity machined graphite heater. The nickel germanium had previously been formed into an alloyed pellet by heating the premeasured constitutents in an evacuated ampoule. For the evaporations of the Ni-Ge on the GaP, the distance was held fixed at approximately 10 cm and the evaporation pressure used was 5×10^{-7} torr. After the evaporation, the temperature of the sample was slowly raised by means of the graphite heater until alloying was seen. That temperature was recorded using a chromel-alumel thermocouple embedded in the graphite. The temperature measurement error was determined by alloying gold, aluminum, and silver on silicon, the alloying temperatures of which are accurately known from the literature.

The results on GaP indicate that with a mixture of 12 to 20 atomic percent germanium, good ohmic contacts are seen. On either side of the proportions rectifying contacts were made. The data is summarized in Fig. 1. As can also be seen from the figure, all alloying temperatures were in excess of 600°C, indicating that stable operation up to 500°C appears reasonable for the Ni-Ge proportions used. In fact, our latest data indicates that the alloying temperatures are in excess of 600°C regardless of composition. For example, pure nickel and pure germanium have been found to alloy to GaP at 805°C and 650°C respectively.

Plans for Next Quarter

The alloying method described will be examined critically to minimize experimental error. The unequal co-evaporation of Ni-Ge and the partial evaporation of the tungsten will be carefully studied. Comparisons will be made between alloying in a vacuum, in an inert forming gas atmosphere, and in a hydrogen reducing atmosphere.

Finally, now that the ohmic contact method seems better defined, attention will be returned to growing thin GaP layers by vertical liquid epitaxy. With our previous results of carrier concentration of $3 \times 10^{15} cm^{-3}$ and breakdown voltages greater than 200v using this technique, consistently good diodes should be possible. Therefore the diodes will be made and tested at temperature.

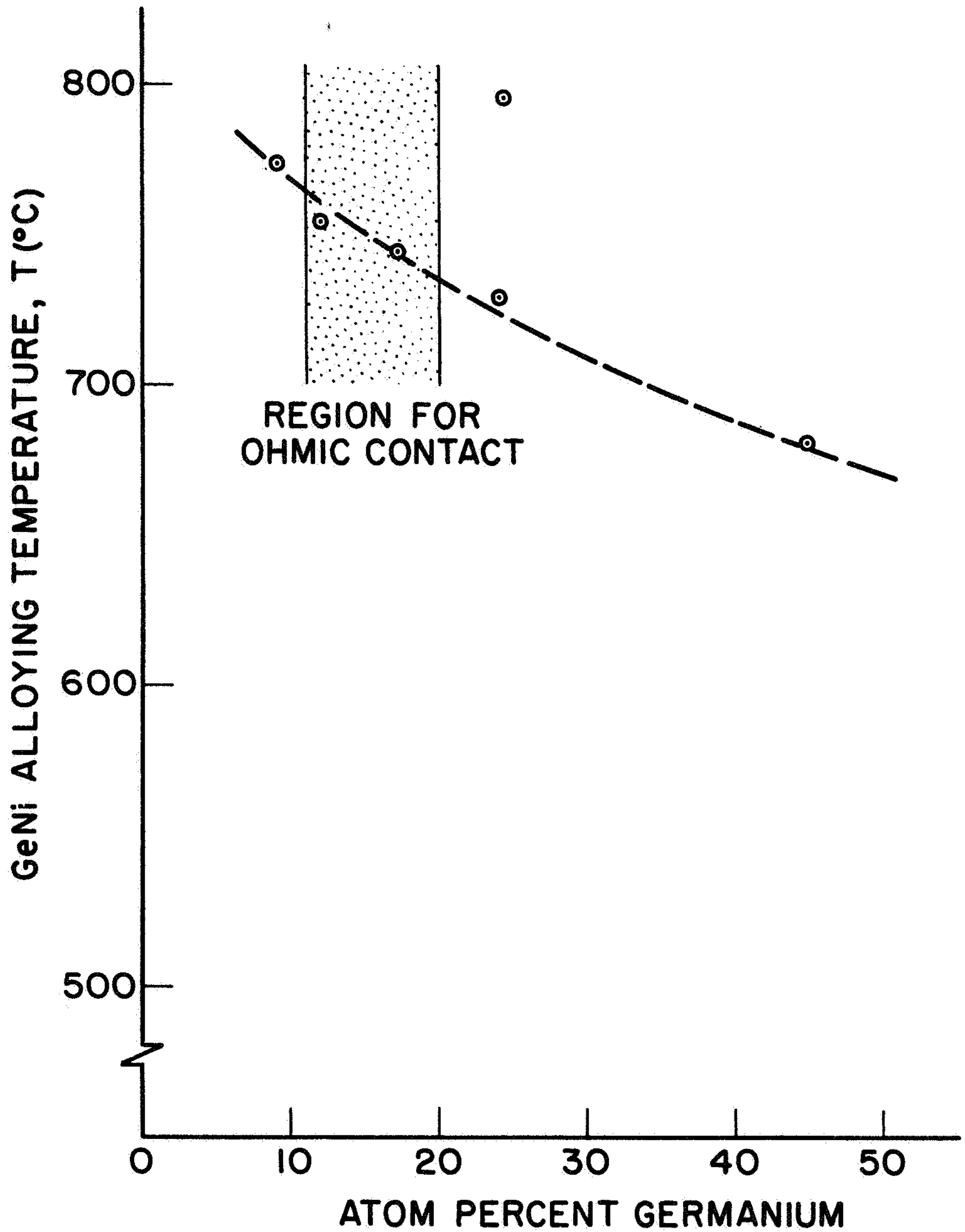

Fig. 1 - Ge-Ni Alloying Temperatures on GaP as a Function of Ge Composition

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